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ABSTRACT

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Improving Science Teaching through Teacher Development Group: A Case Study of Elementary Teachers

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Abstract

Improving Science Teaching through Teacher Development Group: A Case Study of Elementary Teachers

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The purposes of this study were to investigate changes of science teaching and to explore the factors which influencing changes of three first grade teachers when implementing an in-service project. The researcher, the leader teacher and three first grade teachers built a collaborative relationship to hold a teacher development group. The leader teacher introduced the curriculum, Constructivist Rationale and Teaching Model, designed by the researcher to the first grade teachers. Then they cooperatively designed teaching schemes, implemented them, and reflected the problems they encountered in their classes. It was a cyclic and continuous process last for one year. Data from classroom teaching, teacher interviews, student interviews, group discussion, and related document were collected and analyzed. The findings indicated that the three first grade teachers adopted the new teaching model and tried to modify it. They showed teaching behaviors suggested and built a more positive learning climate. In addition to the intervention curriculum and the leader teacher, personal and contextual factors influenced the implementation of the new teaching model. Significant personal factors included teaching beliefs, content knowledge and concern, and autonomy. Time, school culture and leadership, and extra examination were the perceived contextual limitations.

Improving Science Teaching through Teacher Development Group: A Case Study of Elementary Teachers

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INTRODUCTION

Education in Taiwan is highly valued and centralized. Parents, school principles, teachers, and students all have relied on test scores to vale the quality of teaching and learning. Tests have become one of the major factors influencing the teaching practices and quality of learning in school in Taiwan. Because the tests are textbook driven, teachers always cover all the content of the textbooks and put emphasis on repeated exercises that aid the retention of facts to help students get high scores on tests. Students' learning life is full of memorization of facts from textbooks.

People have begun to reflect on the quality of teaching and learning in schools and call for educational reform in Taiwan. Increasingly, people believe that the purpose of science education includes facilitating students' understanding of science knowledge. Facing this changing era, the teacher cannot to be a textbook interpreter only as before. The teacher has to change his or her role into a curriculum designer. How can elementary science teachers improve the effectiveness of their teaching and increase student learning of science concepts?

The constructivist perspective is becoming a dominant paradigm in the field of cognitive psychology. Research findings resulting from this perspective have profound implications for the way in which science instruction is carried out. The science education research community is also contributing greatly to the nature of meaningful learning process. Findings from the research efforts have generated important insights about how students acquire meaning and understanding of science concepts both in and out of school and on how prior knowledge can interfere with and

enhance students understanding. Unfortunately, a vast majority of science teaching in Taiwan is textbook driven and thus often fails to capitalize upon more effective instructional practices stemming from these insights into the cognitive process.

Constructivism educators believe that "Meaning is constructed by the cognitive apparatus of learner"(Resnick, 1983). In other words, meaning is created in the mind of the student as a result of the students' sensory interaction with her or his world. Students make sense of what we present to them by associating the new information with prior knowledge (von Glasersfeld, 1989, 1992; Appleton, 1989). The students must construct it in their mind. The teacher cannot convey or transmit meaning (Saunders, 1992). From the research findings (ex. Champagne, Klopfer, & Anderson, 1980; Whittrock, 1985) it has shown that cognitive structures are sometimes highly resistant to change, even in the face of observational evidence and/or formal classroom instruction to the contrary. When the learner's expectations or predictions do not coincide with experience the result is disequilibration. Disequilibration can result in the modification of one's schema. In summary, learners construct knowledge through a psychologically active process. These knowledge structures are sometimes highly resistant to change. Finally, disequilibrating experiences can result in modification of these cognitive structures and hence give rise to increases in the learners understanding of the world.

Yager (1991) states that, with constructivism, peers are very important in the learning process. Learning is an interpretive process, involving constructions of individuals and social collaboration. Knowledge is created through social interaction as individuals test the fit of usefulness of their conceptual understandings in interactions with others and in contexts in which the knowledge is applied (Tobin, Briscoe, & Holman, 1993). The focus is language and the group. Emphases in constructivist thought include considerations of constructs and processes seen to be

internal to the learned (Freyberg & Osborne, 1985) as well as the influence of the social context and social interactions (Tobin, 1990).

In response to this perspective, science educators have been focusing attention on approaches to teaching science, which take account of students' alternative conceptions. Summarizing the research literature on alternative conceptions in science, Wandersee, Mintzes, and Novak (1994) pointed out that students harbor a wide variety of alternative conceptions about objects and events when they enter formal instruction in science. Moreover, the origin of these conceptions lies in students' diverse personal experiences, which include observation, perception, culture, language, prior teachers' explanation, and prior instructional materials. Students hold tenaciously onto these alternative conceptions in the face of traditional formal instruction. Finally, all of this prior knowledge interacts with whatever is presented in formal instruction, resulting in a variety of unintended learning outcomes by students. There is considerable evidence in the literature, which suggests that discarding or restructuring one's schema does not come easily.

What are important features of effective science program in light of the constructivist perspective? Several models of teaching in science based on constructivist theories have been proposed, such as Sauders (1992). He showed us four instructional features, which stemmed directly from the constructivist perspective. The features include the use of hand-on investigative activities, a classroom environment which provides learners with a high degree of active cognitive involvement, the use of cooperative learning strategies, and the inclusion of test items which activate higher level cognitive processes. In addition, Appleton (1993) outlined nine interventions related to the constructivist perspective to guide practice. A key and necessary change was for teachers to consider the preconceptions of children before they selected activities. In planning activities and links between

them, the interventions would have to be become a new planning frame which would be considered alongside other frame such as time and management.

However the models tend to be limited in scope and provided few clear indications for what a teacher might do to help students learn. An important consideration for teaching practices is the identification and articulation of aspects of constructivism, which provided clear directions for teacher. Bybee, Buchwaid, Crissman, Heil, Kuerbis, Matsumoto, and Mdnerney (1989) proposed a teaching format called the 5 E model. This model suggested a teaching sequence which was engagement →exploration →explanation →elaboration →evaluation. It also provided charts that would help teachers identify their own and student behaviors that supported or contradicted the various phases of the instructional model (IMPACT, 1994).

Research findings on student's understanding on science concepts are gaining more attention and science teachers and researchers are asking questions about possible implications for teaching in the recent years in Taiwan. The study reported here was grounded in the realities of teaching and learning science in elementary school classroom in Taiwan and involved researcher from a teachers college working with a group of local science teachers. The overall strategy was to work with teachers as collaborators in exploring ways of improving students' conceptual understanding in science. This study had two aims: (1) to investigate changes of three first grade teachers' science teaching, (2) to explore factors which influencing the teachers' changes when they implemented an in-service project. The result could contribute to knowledge about teacher professional development.

The In-service Project:

A Collaborative Action Research

An initial open meeting with the leader teacher and three first grade teachers was held at the Charng-Shing Elementary School in 2000 April to outline and discuss the central aim of this project. The researcher and participant teachers all agreed that the aim was to devise, implement, and evaluate teaching materials and strategies that attempt to promote understanding in science concepts and to base teaching on a constructivist view of learning. It was emphasized that the theoretical perspective might be brought to bear on the design and development of teaching schemes, which would be practicable in their primary grade classes. It means that when developing curriculum the participant teachers would take into account factors such as class size, available equipment, and lesson time allocation also. Therefore, it was decided to adopt an interventionist approach to match the aim of the project. During the study the researcher had responsibility for setting the aims of the project, for providing a theoretical framework, for providing guidance in developing curriculum materials, and for monitoring and evaluating classroom practices. The teachers who worked with each other were centrally involved in developing the materials, which they tested in their own classrooms. So the collaborative relationships described here represented both the teacher-teacher and teacher-researcher situations. Based on the constructivist view on learning, it was free for the participant teachers to reject the constructivist approach to teaching or to refine it to make it more useful in their teaching context.

Theoretical Perspectives

Individuals construct their personal knowledge through social interaction and experiences with the physical environment (Tobin, Briscoe & Holman, 1993; Tobin & Tippins, 1993). Learning, therefore, is a purposive activity on the part of the learner

and requires active engagement. Furthermore, individuals' existing conceptions influence the meanings that they construct in a given situation, and what is learned results from an interaction between the learner's existing conceptions and the various linguistic and sensory experiences provided. Designing teaching schemes to support science learning requires some appreciation of the prior knowledge that students are likely to bring with them to the learning situation, while recognizing that individual learners make sense of learning experiences in personal ways. This perspective confers the learners both the power and responsibility to take control of their own leaning, aware of their personal epistemological commitments, represent conceptions to their peers and teacher, and monitor their interpretations of scientific phenomena and expressed views of others (Hewson, Beeth & Thorley, 1998)

Teaching Format

There are several constructivist formats one can use. The one the researcher chose was developed by Biological Sciences Curriculum Studies (BSCS) and is called the "5E" model. The chief developer of the model, Rodger Bybee, bases the constructivist teaching plan on five instructional phases: the Engagement, Exploration, Explanation, Elaboration and Evaluation. According to Bybee *et al* (1989) the Engagement is presented to the students to initiate interest and excitement in the topic; the Exploration encourages students to investigate and discuss different aspects of the topic in small cooperative groups; the Explanation gives students chance to describe to others what their team has discovered; the Elaboration provides the opportunity for the students to expand and investigate the topic further; and the Evaluation allows the students and the teacher to assess what students have learned in exploration (E2), explanation (E3), elaboration (E4), and evaluation (E5).

The Teachers and School Context: Jane, the leader teacher, had been elementary science teacher for ten years. She had earned her master degree and many

outstanding awards. After finishing the "Science Leader Teacher Preparation Program"(Lin, 2001), Jane invited her collogues, Anne, Barbara, and Cathy, to attend the teacher development group. Anne, Barbara, and Cathy had been primary grade teachers for five, nine and thirty years separately. They all worked at a public school in the middle social-economic class areas near Pingtung City in the southern Taiwan. In the three teachers' classrooms, the children were seated in line. The classroom climate was purposeful. During the group activities the teachers would provide the professional and social support to each other within the school. In addition it was anticipated that the teachers would bring a breath of ideas and skills to the task of curriculum development and also would offer different classes in which the materials might be tried out.

Design and Implementation of the Project: The three first grade teachers were asked to describe their teaching objectives, teaching characteristics, and roles in their science classes. The above activities were to help both the researcher and participant teachers to reflect systematically on their existing practice. Jane introduced the intervention curriculum, Constructivist Rationale and Teaching Model (Lin, 2001), designed by the researcher to members of the group. Then, Jane and the three teachers worked cooperatively to discuss the constructivist view of learning and generate teaching schemes as suggested in the intervention curriculum. The three first grade teachers tried the new schemes in their classes. The subject matter on juice, cold and hot, leaves, lovely animals, toast, and sound were documented in detail by the researcher who observed and tape recorded all lessons of the above topics. During these trials, regular meetings allowed participant teachers and the researcher to review each instructional activity in the light of the sense that students had made of it and the problems that they had encountered.

METHOD

This was an interpretive case study consisting of the interaction of theses teachers and the three primary grade teachers' implementation of science topics over a year period. Classroom observations, interviews, and documents were used to collect related data. The researcher and Jane provided some support for the teachers in this group both as a source of ideas and suggestions during the study. During classroom observation, the researcher acted as a silent observer sitting at the back of classroom. The researcher and teachers constructed the vignettes of this study.

Data Collection: Fieldwork for the case study comprised one year during which time narrative data was gathered. The data sources included observing 30 consecutive meetings, interviewing teachers, and collecting teaching documents. A stratified random sampling technique was used to select six students from each first grade teacher' class. These students were interviewed about their perception of learning environment.

Analysis: Tape recordings were transcribed. Teaching plans and practices were checked according to "Teaching Practices Checklist"(IMPACT, 1994; Lin, 1998). A chronological vignette of the development of the topics was constructed from the various data sources by the researcher. Analysis of the data relating to the group led to the following categories: teacher characteristics, critical reflection of participants, trying out of activities in the classroom, classroom climate, and factors affecting teacher change. Interpretations were fed back to the four teachers for their comments.

RESULTS

Results presented the changes in three teachers' science teaching during the study in terms of three categories: teaching sequence, teaching strategies, and classroom climate. There were three groups of factors that seem to influence teacher

development: personal factors, intervention factors and contextual factors. These three factors interact in a complex manner, affecting each other and in turn influencing teacher development.

Changes of science teaching

The participant teachers adopted the learning cycle gradually and they tried to modify it to their teaching conditions in the end of the year as showed in the figure 1. They used a number of different instructional strategies in the new teaching approach that being matched to the nature of constructivism

Teaching sequence: Anne, Barbara, and Cathy had never heard about the 5E model before and this was the first time that they tried this model. Based on the suggested model, they played a central role in curriculum development. The previous teaching sequence, introducing concepts or providing definitions and answer then providing activities for students to verify it, didn't present again in the new approach. They always followed the suggested teaching sequence of "5E" (E1 →E2 →E3 →E4 →E5) in the begin of new trial. Anne, Barbara, and Cathy modified the 5E linear sequence to a more interactive and flexible sequence in their classes (see figure 2) toward the end of the year. Unlike the unidirectional approach to the five phased of 5E model, a student might return to any phase if needed. In addition, the evaluation phase was more formative in their teaching. The three first grade teachers would use different strategies to assess their students on attention, understanding, involvement or achievement in any phase of the model.

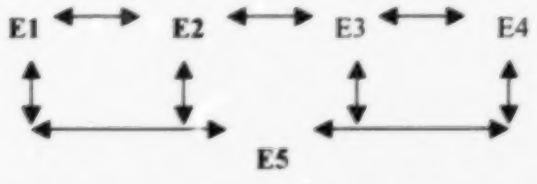

Fig.2. Three first grade teachers' instructional sequence.

Teaching strategies: Within the 5E instructional sequence, a number of different instructional strategies were used in the three first grade teachers' classes, with each being matched to the nature of constructivism (see table 1). In the engagement phase, Anne, Barbara, and Cathy did good job in creating interest, generating curiosity, and raising questions as before. The frequency of uncovering what the students had known or thought about the concept/topic when taught each concept was increasing during the research.

In the second phase, the exploration, Jane and three first grade teachers cooperatively designed activities to encourage students to investigate and discuss different aspects of the topic in small and cooperative groups. Students worked in-group was an unusual activity in three first grade teachers' previous teaching. Both the teachers and their students took time to learn how to play the new roles suggested by the researcher.

Anne, Barbara, and Cathy were accustomed to lecturing instead of listening in their previous teaching. They learned how to give students chances to describe to others what their group had discovered in the explanation phase. The management of whole-class discussions in ways that respected the contributions of individuals while maintaining a clear direction was also seen as particularly demanding to the teachers.

Anne, Barbara, and Cathy all indicated that the elaboration was the most difficult phase for them to practice. Cathy said, "It is not easy to design a right activity for providing the opportunity for students to expand and investigate the topic in everyday or new situation." Brainstorming was the strategy the participant teaches used to solve this problem.

During the evaluation phase, Anne, Barbara, and Cathy throw the student

workbook away and developed new assessment strategies to evaluate their students. They created observation checklist, discussion, journal writing and worksheet to monitor student attention, involvement, understanding or achievement during their new trial.

The central aim of this team was to devise, implement and evaluate teaching materials and strategies that attempted to promote understanding in science concepts and to base teaching on a constructivist view of learning. All participant teachers reflected on their planning and classroom actions and adopted the suggested theory and the teaching format to generate new learning activities for subsequent trial, evaluation, and modification.

In general, the participant teachers showed positive attitude toward the new approach. In addition, the insights offered by research provided teachers with a rationale for thinking about teaching and learning. For the participant teachers, it was the first time since their initial teacher training that they had looked at practice from a reflective and theoretical stance.

Classroom Climate: The dada from student interviews on classroom climate generated the following findings.

Doing more experiment. The opportunity to be involved in experiment was valued by all interviewed students. Students were able to take a more active role in the construction of the practical experiments. For example:

> We mostly did experiment. Do experiment is more fun and exciting. (S 12/01)
> We worked out the concepts during the experiment instead of just coping it out of a book. (S 21/03)

Science is more fun. Students were happy in their science class. Learning science was easier and happier:

> It made us be involved, learning became more interesting. (S 12/03)
> It's much more fun, rather than just memorize facts. (S 8/02)
> I can learn all content in the science class. Science is not difficult to me. My science class is fun. (S 35/03)

Teacher support. Students like their science class because their teacher helped them friendly. They feel comfortable to ask for help.

> The teacher will ask if I have any question. (S 12/02)
> The teacher will help me if I ask. (S 30/01)
> The teacher looks like a friend to help me. (S 8/02)

Think input. Students' own ideas were listened to and valued and they felt that they had more input and involvement in lessons than was previously the case. Students were encouraged to develop their own ideas:

> My science teacher would not tell an answer is wrong, she just asks us to change it in some way to come to a more satisfying result. (S 12/02)
> It made one think, question, and investigate, instead of writing down things. (S 30/02)

More discussion. Students reported that they were given more freedom in class than previously, could discuss their ideas more openly and in more detail. The following comments were from students who stated:

> Because we could express our own ideas freely instead of being taught the teacher's ideas. (S 18/01)

> I enjoy my science class because everyone's ideas are considered to be valued; we all get a chance to express our ideas. (S 23/02)

Less note taking. Students reported that fewer notes were copied down with many being suggested by themselves, the blackboard was used sparingly and there was minimal use of textbooks. Students stated that:

> I liked how we were the ones to carry out investigations to answer questions and not copy out slabs out of books. (S 19/02)
> It was more interesting because it didn't involve simply writing pages of notes. It was a more practical course. (S 24/01)

A few students were unsure if they liked the constructivist classroom with expressing a desire to be told information rather than constructing knowledge and having to think for themselves. A student, for example, preferred the use of the blackboard:

> I prefer the teacher/blackboard approach that the teacher tells students things. It was easier for me to catch the key points. (S 18/01)

Some low-achieved students reported that they did not like the constructivist approach because there were too many different views given that caused some confusion. The concern for the students who did not like the approach was shown in the following remarks:

> I don't think so, because it gets me a bit confused with my answer and with the right answer. (S 3/01)
> It was difficult to fully understand. Because of the many ideas created from the class, this often caused some confusion. (S 14/02)

In summary, not all students were in agreement that constructivist teaching/learning approaches were beneficial to them. The majority of students, positive about the approaches, identified the issue of a need for more teacher control of learning via blackboard notes to prevent confusion in their understanding of concepts.

Teachers' perceptions of factors influencing their changes

There are three groups of factors that seem to influence teacher development: those involving the teacher as a person, those relating to the context in which the teacher lives and works, and those involving interventions to foster teacher development. These three factors interact in a complex manner, affecting each other and in turn influencing teacher development.

Intervention curriculum and the leader teacher: The three teachers indicated that the intervention curriculum designed on constructivism and the teaching model was helpful to them. They said that it was easier for them to comprehend what was constructivism teaching. They all agreed that the intervention curriculum provided them with theory, practices and evaluation tools was useful for them to follow with quickly. Anne, Barbara, and Cathy indicated that there existed the strong influence exerted by the leader teacher. They all agreed that Jane was an exemplary elementary science teacher that they could learn lots from her and that Jane helped them friendly to be more confident in science content and pedagogy.

Personal factors: Anne, Barbara, and Cathy mentioned that beliefs, content knowledge and concern, and autonomy were the most significant personal factors affecting their changes.

Belief system. Anne said," I can perform successfully." Barbara said," The actions I take will achieve the results I want." Cathy indicated, "The results I achieve will be

recognized by rewards that I value." The above beliefs were essential for changing. Teacher's content knowledge and concern. Barbara's major was social science. Cathy's major was mathematics. Lack of confidence in science was the major barrier that Barbara and Cathy did not know how to improve their science teaching. To increase their science content knowledge, they used information from college textbooks, encyclopedia, and science journals. In addition Jane shared science information with the rest or them, along with some information about how to teach science for understanding. Barbara said," It illustrated to me the importance of using appropriate strategies to help students what they are learning." Anne had some problems in classroom management. The other teachers shared information with and provide suggestions for her.

Autonomy. All three teachers loved teaching. Jane thought that she could make some contribution to the 1 to 9 integrated curriculum reform. Anne thought teaching was meaningful work. Barbara believed that she could be a better science teacher. Cathy loves students and wants to help them to learn happily. These teachers all had an appropriate degree of autonomy in the significance of their work. The autonomy facilitated them to try, evaluate, and take actions.

Contextual Factors: The teachers recognized pressures that affected their capacity to translate ideas into classroom practice. The most constraining ones referred to the importance were the following: Time, school context, and conflicting pressures on the examination.

Time. Teachers in Taiwan worked long hours and there were very little non-working time. Under these conditions, teachers felt overworked and unable to plan change and to try new approach:

> I like the idea of constructivism. In theory, it is very good. But I have to prepared and

teach eight different subjects. There is limited free time. How can I apply what is suggested in the intervention curriculum?

Their non-teaching time was restricted to correcting student worksheets, filling out student personal data forms, and official meetings: we need time to plan, to be creative, and to introduce new teaching strategies. We cannot link research and teaching if there is no time.

Not only was there lack of time to translate what was being discussed into teaching and learning strategies, but also time for group meetings was limited within their school and if another matter requires urgent discussion, group meetings may be canceled. Despite this, we observed group meeting on a Saturday morning or in the evenings after school. In all cases, we are speaking of unpaid time.

School Context and Conflicting Pressures. It was advantageous that the leader teacher, Jane, was open to change, and it was also an advantage that the participant teachers felt committed to it while at the same time recognizing the need for changes. In this school, the administration was barely supportive of the teacher groups. No adequate room space was provided for meetings. This school limited the time and space for group meetings. Jane and three first grade teachers tried to establish a school culture based on norms of collaboration and professional inquiry and to recast routine administrative activities into powerful teacher development strategies.

The teachers perceived conflicting pressures coming from different sources. On the one hand, there were those resulting from introducing changes, without the rest of the system having changed to suit the new situation. Also, while the in-service program wished teachers to take time during the teacher professional group sessions to think out their change strategies, it also asked them to develop school improvement projects and recently to implement the "1 to 9 Integrated Curriculum Reform".

Another source of conflicting pressures was the pressure of having to show good examination results, while at the same time being called to think and be innovative in teaching and learning strategies.

Examination: Having to show good examination result was a conflicting pressure. Anne said,

> As a teacher I feel as if I am split into two parts. First, the project calls me to reflect and to be a curriculum designer. On the other hand, my students have to take an extra examination. Based on the examination result, school administrators and parents evaluate my teaching effectiveness.

While these contextual limitations were important and if not remedied at least to some extent they may hinder the possibilities of changing classroom practices and student learning, it was also true that teachers in many of the groups visited worked together with much energy and enthusiasm as if these limitations did not exist.

What Has Been Learned From the Implementation of teacher development group?

The participant teachers in this study resulted from spontaneous teacher action and from a change project proposed by an external college researcher to the school as a condition for such a project become operational there. In this group, structures and materials were considered as offered but not necessarily accepted. Affected by the manner in which the leader teacher interpreted materials and conducted meetings, the group contrived change and created their own mode of operation. They discussed jointly their teaching experiences in the classroom, learned from each other and reflected on what works or does not.

The strong reform target of improving student learning in the primary school caused the researcher to orient teacher development group's activities along these lines, both in the

structure and the activities offered for the groups to work on. Did these structures and materials respond to teachers' needs to develop in the ways they saw fit and feel professionally satisfied? For the teachers, the materials and structures were taken as offers and accepted or rejected according to needs. All these postures represented valid viewpoints, and to a certain extent one could determine from the nature of the justification given for each position that resulted from collaborative reflection.

The core of the achievements of the project in this worked well group seemed related to the manner in which it satisfied personal needs of participant teachers and their felt need to share professional issues with others: "It has allowed us to see ourselves individually as professionals and collectively as equals who are sharing a common task of education." To the extent that teachers valued the information to which they had access and the opportunity to work it through or to look for their own sources of information, teacher development group was also responding to professional needs and to the shortfalls of traditional in-service.

It was very important to provide support to elementary teachers to improve their teaching in science. The participant teachers indicated that beliefs, content knowledge and concern, and autonomy were the most significant personal factors affecting their changes. The researcher and the leader teacher would encourage the participant teachers to change their belief system toward the action value, help teachers to gain their confidence in science content and pedagogy and make them believed that they could be a better science teacher and facilitating them to try, evaluate, and take actions. Jane, the leader teacher, served as the important catalyst to developing a support team in our case. Anne noted the importance of having someone with first grade teaching experience helping others improve their science teaching because that person had common experiences and knew what it was like to teach first grade students. Perhaps a way for elementary science teacher education to take this result is to increase collaboration with college researchers, to find an exemplary elementary science teacher to serve as leader or mentor to other teachers in one school or in preparing teachers to

support each other's work.

The factors discussed in this article as contextual constraints affecting the achievement of the group are practically the same as those discussed in the literature. Without "time for change" we cannot expect teachers to change and in Taiwan, the situation was particularly critical: too much is being asked from teachers and too much is expected of the reform, without sufficient attention to the time factor.

The experience of "troubling contradictions" (Murphy, 1993) by schools and teachers seemed without there being any short-term solution in view. "Constant frustration" noted by Stenhouse (Weeden, 1987) as a factor against the success of reforms, is clearly the experience of the teachers observed or interviewed, either because of the weight of work and the lack of time, or because of school administrations that do not support a collaborative environment. Some of the constraints are being dealt with, such as work with the leader teacher to assist them in creating more participative school environments.

From this case the primary teachers can develop into effective science teachers. By collaboration with the college researcher and their own involvement in changing their teaching practice, they developed their own appropriate curriculum. They become willing to learn more science content and pedagogy to use it for developing teaching units. The empowerment they felt by their involvement in their developments helped them remain committed to their science teaching. Elementary science teacher education can take from this idea to encourage primary teachers to cooperated with researchers and provide more input in developing curriculum and in improving science teaching.

Despite evidence of good results in this school, it can be predicted that critical moments are ahead, as the teacher development group "grow old" and the college researcher ceases the direct support. Teachers will expect to see changes in their classrooms and their students, and will expect changes in the educational system that ease the constraining factors under which they work. To avoid frustration, demands on teachers should be reasonable and coordinated,

their views and their pace of development should be respected, and gains in difficult conditions should be recognized even if the school is not given first place in the league. The teacher development group will need time and faith in its possibilities, not just resources, to persevere in its current efforts and future actions towards improving student learning in the school.

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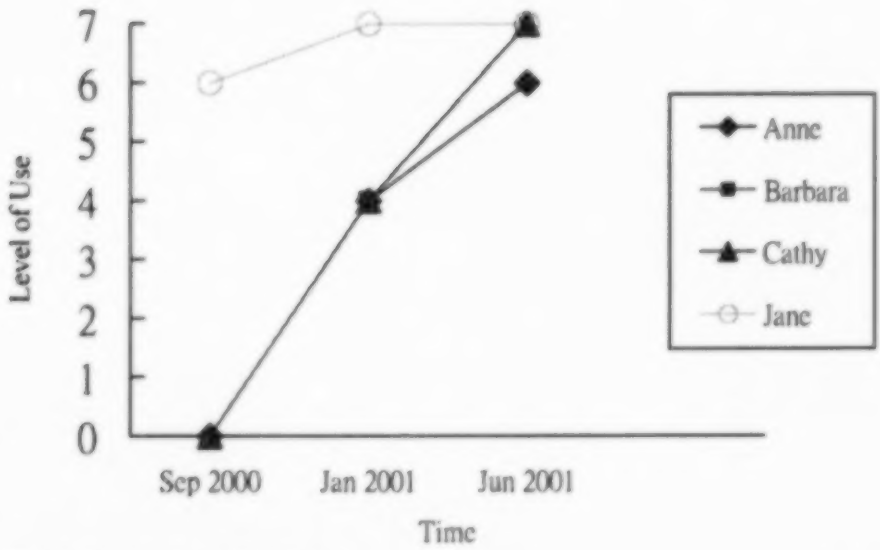

Fig. 1. Level of use distribution.

Ps. Level of use: 0:nouse, 1:orientation, 2:preparation, 3:mechanical use, 4:routine, 5:refinement, 6 integration, and 7:renewal

Table1. The participant teachers' teaching strategies during the research

Stage	What the Teachers Do	Fall 2000	Jun 2001
Engage	· Creates interest	2	4
	· Generates curiosity	2	4
	· Elicits responses that uncover what the students know or think about the concept/topic	2	1
	· Explains concepts	2	1
Explore	· Encourages the students to work together without direct instruction from the teacher	1	3
	· Observes and listens to the students as they interact	3	3
	· Asks probing questions to redirect the student's investigations when necessary	1	2
	· Provides time for the students to puzzle through problems	2	2
	· Acts as a consultant for students	1	3
	· **Tells or explains how to work through the problem**	4	1
	· **Leads the students step-by-step to a solution**	4	1
Explain	· Encourages the students to explain concepts and definitions in their own words	1	3
	· Asks for justification (evidence) and clarification from students	1	2
	· Formally provides definitions, and new labels	3	4
	· Uses students' previous experiences as basis for explaining concepts	1	4
	· Neglects to solicit the students' explanations	3	1
Elaborate	· Expects the students to use formal labels, definitions, and explanations provided previously	1	2
	· Encourages the students to apply or extend the concepts and skills in new situations	1	2
	· Reminds the students of alternative	1	1
	· Refers the students to existing data and evident	1	2
	· Lectures	3	1
	· Leads students step-by-step to a solution	3	1
Evaluate	· Observes the students as they apply new concepts and skills	2	3
	· Assesses students' knowledge and/or skills	1	2
	· **Looks for evidence that the students have changed their thinking or behavior**	2	1
	· Allows students to assess their own learning and group-process skills	0	2
	· Asks open-questions	1	3
	· **Tests vocabulary words, terms, and isolated facts**	4	1

Ps. Mean that is inconsistent with suggested strategies

1.Almost Never (1%~20%) 2.Seldom(21%~40%) 3.Sometimes (41%~60%)

4.Often(61%~80%) 5.Almost Always(81-100%)